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(GB)**(54) **Improved apparatus for remotely determining the position of rotating objects.**

(57) An electric field is generated in the vicinity of a rotating member to be monitored. The electric field is so constructed as to include a resultant vector representing maximum field strength rotating in a path parallel to the circumferential path of the rotating member. A sensing or reading device is positioned at the rotational axis of the resultant vector for detecting variations in the field strength therein as the vector passes the rotating member. The sensing device creates a periodic electrical output whose relative phase is responsive to and indicative of the angular orientation of the rotating member. The electric field with the rotating resultant vector is formed by generating a polyphase voltage having a plurality of signals, each signal separated from the others by a prescribed phase angle, and wherein each signal is shaped as a square wave. Each of the signals is applied to one of a plurality of exciting electrodes which are arranged in a circular array around a center point aligned with the axis of rotation of the resultant vector. Successive electrodes in the arrangement are connected to successive signals of the polyphase voltage.

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IMPROVED APPARATUS FOR REMOTELY
DETERMINING THE POSITION OF ROTATING OBJECTS

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Background of the Invention

In an earlier United States patent no. 4,007,454,
issued to Charles Cain et al, there is disclosed the
technique for generating and using what is referred to
as a "rotating electric field" in a device for remotely
5 measuring the orientation of a meter hand or other
rotating object. Further testing and analysis has
shown that the theory of operation of the invention of
the aforementioned Cain et al patent is clarified by
considering that the portion of the field which is
10 generated in the space adjacent the meter hand or other
rotating object to be monitored is such that the re-
sultant vector representing maximum strength of the
electric field rotates, by which means the effect of
a "rotating electric field" is approximated or approached.

15 In the Cain et al apparatus mentioned hereinabove
there is described a circular array of electrodes with
a detecting electrode located at the center of and co-
planar with the array. By applying the successive
phases of a polyphase voltage to successive electrodes
20 in the circular array, the maximum field strength
vector is thus caused to effectively rotate in the
adjacent space to accomplish this rotating effect of
the maximum field strength vector. Diametrically
opposite pairs of the aforementioned electrodes are
25 connected to successive phases of a polyphase voltage
source in such a manner as to produce the rotating
effect of the maximum field strength vector.

Various changes and modifications have been made
to this basic invention as disclosed in patent 4,007,454.
30 For example, one such change is disclosed in
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In the aforementioned application the shape of the electrodes themselves are changed. Tests have shown that this gives an improved output linearity to the arrangement. Another improvement is the subject of United State patent No. 4,214,152, issued July 22, 1980, in which there is an interdial error correction technique introduced to the circuitry thereof.

Even with these improvements there exists certain problems in the generation and use of the electric field. By "polyphase" it is meant that each signal lags behind its neighbor somewhat. The earlier teachings referenced above have utilized six sine waves separated in phase by 60°. With the sine wave each drive signal rises and falls smoothly as time progresses.

Summary of the Present Invention

In the present invention it was first theorized that perhaps square waves might be preferable to a smoothly rising and falling sine wave in such an environment for several reasons. First of all, square waves can be generated by considerably simpler circuitry. The phase relationships between the various phases can be more reliably maintained so as to improve the stability, reliability, and sensitivity of the encoder. This is so because the shapes of a square wave would be less likely to change with aging of circuit components. Stronger signals back from the center electrode would occur because (a) a slightly higher voltage can be more conventionly and reliably applied to the electrodes with the same power supply as digital drives can run essentially "rail to rail"; and (b) the effective energy coupled increases because of the square shape so that the square wave contains abrupt discontinuities which act like high frequency signals.

Tests have confirmed the theoretical preference to the extent that there has been realized approximately 30% reduction in circuitry complexity, very significant improvement in stability, and less sensitivity to circuit parameters which are subject to change with age, e.g. values of resistors and capacitors. The

increase in signal strength was found to be significantly greater than expected.

5 In its broadest and most general terms then, the present invention is directed to an improvement in the apparatus disclosed in the earlier Cain et al patent no. 4,007,454 by the changing the input signal from a plurality of smoothly rising and falling sine waves to a plurality of signals each separated from the other by a prescribed phase angle, and each signal being shaped
10 as a square wave.

 Such square wave generation can be accomplished according to well-known procedures which include the delivery of the input signal to an oscillator to provide an oscillating signal, followed by the delivery of the
15 oscillating signal to a phase splitter which splits the oscillating signal into a polyphase voltage. The polyphase voltage may be two phase, three phase, or any other number of phases. Three phase voltage is perhaps preferably because it is frequently available from
20 conventional power lines. Therefore the six phases could be the three original phases and their inversions. By driving the signals through squaring amplifiers the sine waves may be reshaped into a square waves and applied to the encoder. In a preferred embodiment,
25 however, the technique for generating the six square wave signals is accomplished digitally in a three stage Johnson counter.

 It is therefore among the objects of the present invention to provide an improved transducer for monitoring the angular position of a meter hand or other
30 rotating body as it rotates about an axis of rotation by utilizing the type of encoder generally described in U.S. Patent 4,007,454, except by utilizing a series of square wave input signals.

A further understanding of the invention will become more apparent from reading the following detailed description of a preferred embodiment along with the accompanying drawings in which:

5 Figure 1 is a schematic diagram showing a transducer according to the present invention in conjunction with the improved control circuit and a recording circuit therefore;

10 Figure 2 is a schematic wiring diagram showing the connection of the transducer with the input and reading circuits; and

Figure 3 is an electrical schematic showing a preferred type of square wave generating sub-circuit and filter for use in the present invention.

15 Detailed Description of A Preferred Embodiment

In general terms, the present invention provides means for producing an electric field in which the resultant vector representing the maximum field strength vector rotates as a set of polyphase voltages is successively (by phase) applied to members of an electrode array with a reading means at the center of rotation of the resultant vector. Other than modifying the shape of the applied polyphase signals from a sine wave shape to a square wave shape the interrogating and comparing
25 circuitry is the same as that disclosed in the Cain et al patent 4,007,454 and it is here incorporated by reference. The polyphase square wave signals may be applied to an electrode array that is set forth as described in the Cain et al patent 4,007,454, or it may
30 be applied to an array of electrodes as set forth in GB - A - 1 592 694.

Referring now to Figure 1 of the drawings, a transducer generally designated at 10 is positioned adjacent the face of a meter 11 having a hand 12. A
35 reading means 14 in the form of an electrode, or other electric field sensing device is positioned at the

center of the transducer 10, the reading means being connected to the line 15 in which there is a phase comparison circuit 13 of conventional and well-known design or by well established digital means. The
5 transducer 10 is also positioned such that the axis of rotation of the resultant vector of the electric field coincides with the axis of rotation of the meter hand 12.

It will be understood that the wire 16 is from a
10 source of electrical voltage, such as single phase, double phase, three phase, or any phase. Generally, however, electric power lines and the like use single phase voltage. A signal monitoring device 17 of conventional design is arranged so as to ignore routine
15 voltage changes occurring on wire 16 but to detect special voltage patterns (which may be superimposed thereon by the remote station and which constitute a request for a meter reading) and respond thereto by closing a switching device such as is represented by
20 relay L1. With this arrangement the relay L1 or other switching device can be remotely energized to activate the transducer 10.

The wire 16 leads to a square wave signal splitter/generator 18 which converts the single or other phase
25 voltage into a plurality of phases, for example, three phases to provide the electric field with the rotating resultant vector. Thus, when it is desired to read meter 11, an interrogation signal is placed on the wire 16 which causes the signal monitor to energize the
30 relay contact L1-1. When the contact L1-1 is closed, the single phase voltage through wire 16 which will be split by the phase splitter/square wave generator 18 into a polyphase square wave voltage; for example, as illustrated a three-phase voltage. At the same time,
35 as an inherent advantage of the properly connected polyphase voltage, an electric field having the resultant vector thereof representing the maximum field strength vector will be generated to rotate around the face of transducer 10. When the rotating resultant vector

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crosses, or becomes parallel to, the dial hand 12, a maximum voltage will be induced in the reading means 14 from which the phase angle can be determined. It is not necessary that the hand 12 be magnetized, or even electrically conductive, as long as the dielectric constant of the material from which the hand 12 is formed differs significantly from that of the surrounding medium... Generally, any material will work such as metal, ceramic, or plastic.

As illustrated in Figure 2, it can be seen that the wire 16 is connected through relay contact L1-1 to the phase splitter/square wave generator 18. The details of the phase splitter 18 in its preferred form are illustrated in Figure 3. The circuitry for the preferred embodiment of the invention in which the poly-phase square wave signal is basically generated by the use of a three-stage Johnson counter. The incoming signal is divided into six square wave outputs that are separated in phase by 60 degrees. It should be understood, however, by those skilled in the art that the phase splitter 18 can provide polyphase voltage, that is voltage of two phase, three phase or any other number of phases. Three phase voltage is perhaps preferable because three phase voltage will frequently be available from the conventional power line so that the phase splitter 18 will not be required. If three phase voltage were available from the power line, there will be three contacts such as contact L1-1, one of the contacts being in each of the three phase lines, and the phase splitter 18 could be replaced by three phase inverters so that the input to the square wave generator G would consist of the three original phases and their inversions.

In the square wave generator G each signal could alternatively be treated by first of all subjecting it to a crystal oscillator, followed by re-shaping by capacitors, resistors, amplifiers and the like to form six outgoing signals, each having a square wave, separated approximately 60° in phase from each other.

Each of these polyphase square wave signals could be applied to the transducer 10 in the same manner as disclosed in prior patent 4,007,454 which is incorporated herein by reference.

5 With this arrangement and as illustrated in Figure 2, it can be seen and understood by those skilled in the art, that when one phase reaches its peak voltage, there will be an electric field between the electrodes 20 and 23, one of the electrodes being positively
10 charged and the other being negatively charged. One hundred twenty (120°) electrical phase degrees later when the phase B reaches its peak voltage there will be a strong electric field between the electrodes 21 and 24, one of the electrodes being positively charged and
15 the other being negatively charged; and the same situation will be true for electrodes 22, 25 when phase A is in the middle of its peak voltage time. Thus, the rotating resultant vector effect is provided.

As far as the reading of the outputs from the
20 transducer 10 by the phase comparator 13 is concerned, there will be a substantial difference than that shown in patent 4,007,454. Whereas in the phase comparator of Patent No. 4,007,454 a set of sine waves were formed by filtering a plurality of signals, and presenting the
25 plurality of sine waves to the electrodes, the resultant combination summed and compared, now the process is as follows. The set of square waves in the present approach are presented to the electrodes without fitting, the resultant combination of signals is then summed, filtered
30 through a single filter and compared. Thus only one filter is necessary. Further, the filtering and/or phase determination of the summed output can be achieved through well established digital techniques.

While the present invention has been described in
35 detail hereinabove, it is apparent that various changes might be made without departing from the scope of the invention which is set forth in the appended claims.

CLAIMS

1. An improved apparatus for remotely monitoring the angular position, speed, and/or direction of rotation of a member as it rotates about an axis of rotation and defines a circumferential path comprising:

- 5 a) means for generating an electric field in which the resultant vector representing maximum field strength rotates in a path parallel to said circumferential path of the rotating member and includes said circumferential path therein;
- 10 b) a reading electrode means fixedly positioned within said electric field and symmetrically placed with respect to said axis of rotation for sensing a voltage change responsive to the crossing of
15 said rotating member by said resultant vector and emitting an output signal responsive to said voltage change; and
- 20 c) said means for generating the electric field and said reading electrode both being positioned in confronting, spaced relation to, but in no way otherwise mechanically or electrically
25 connected to said rotating member other than that a portion of said rotating member is within the path of
30 said rotating electric field,

35

d) said means for generating a 0053446
rotating electric field com-
prising:

40

i) means for generating
a polyphase voltage
having a plurality
of signals, each
separated from the
other by a prescribed
phase angle, and
each signal shaped
as a square wave;

45

ii) a plate positioned
in spaced, confront-
ing, parallel
relation to said
circumferential
path;

50

iii) a plurality of
exciting electrodes
defining a circular
array around a
center point aligned
with said axis of
rotation of said
rotating member,
successive electrodes
being connected to
successive signals
of said polyphase
voltage.

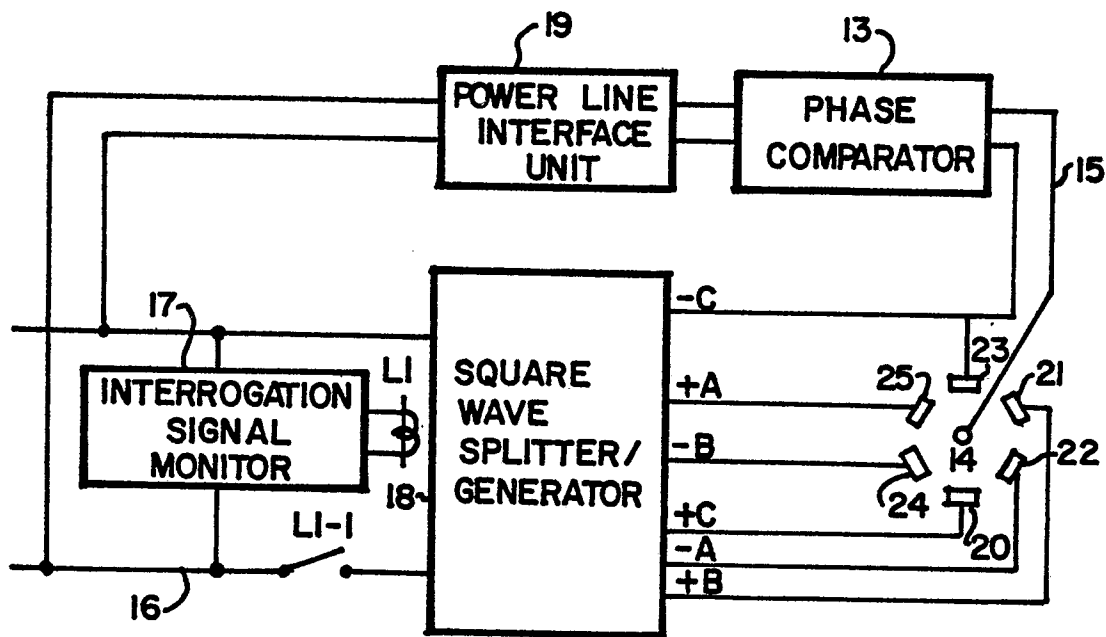
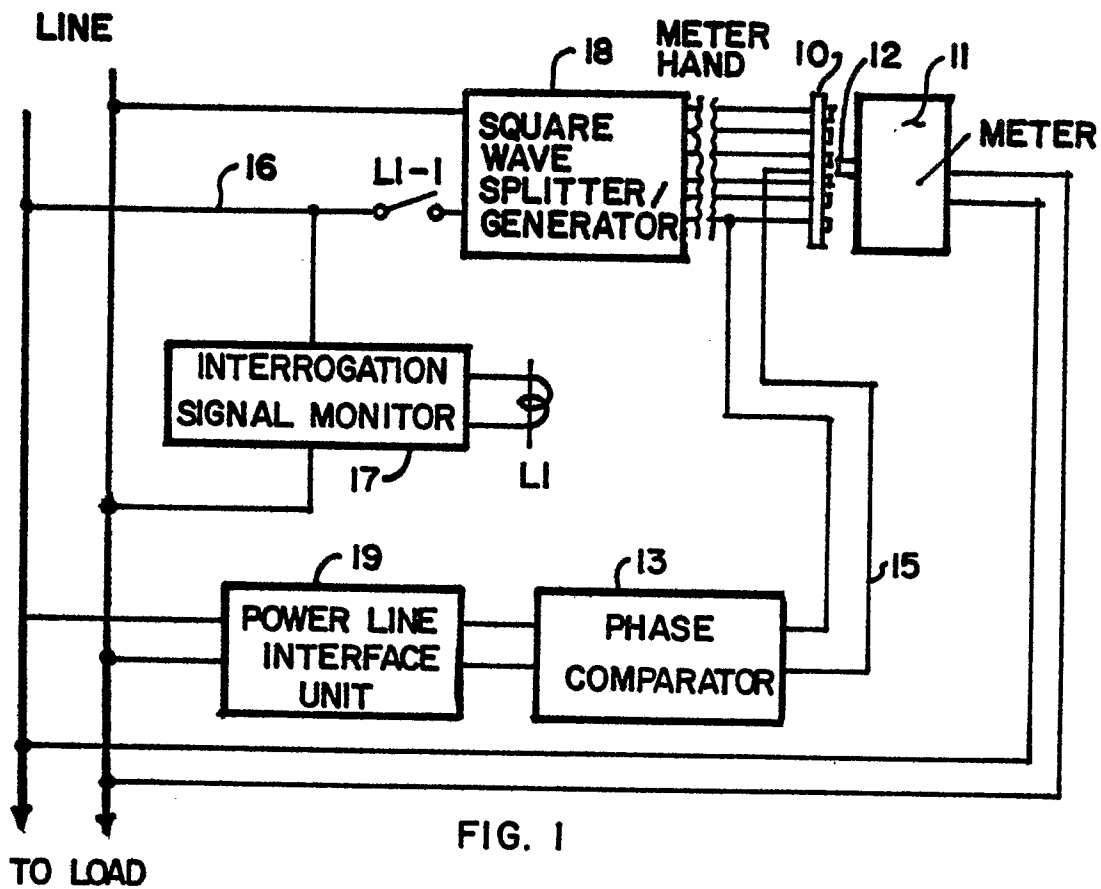
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2. The apparatus according to Claim 1 and 0053446
further including a filter device electrically downstream
of said reading electrode and a phase comparing means
electrically downstream of said filter device for
5 determining the resultant phase angle which corresponds
to the position of said rotating member.

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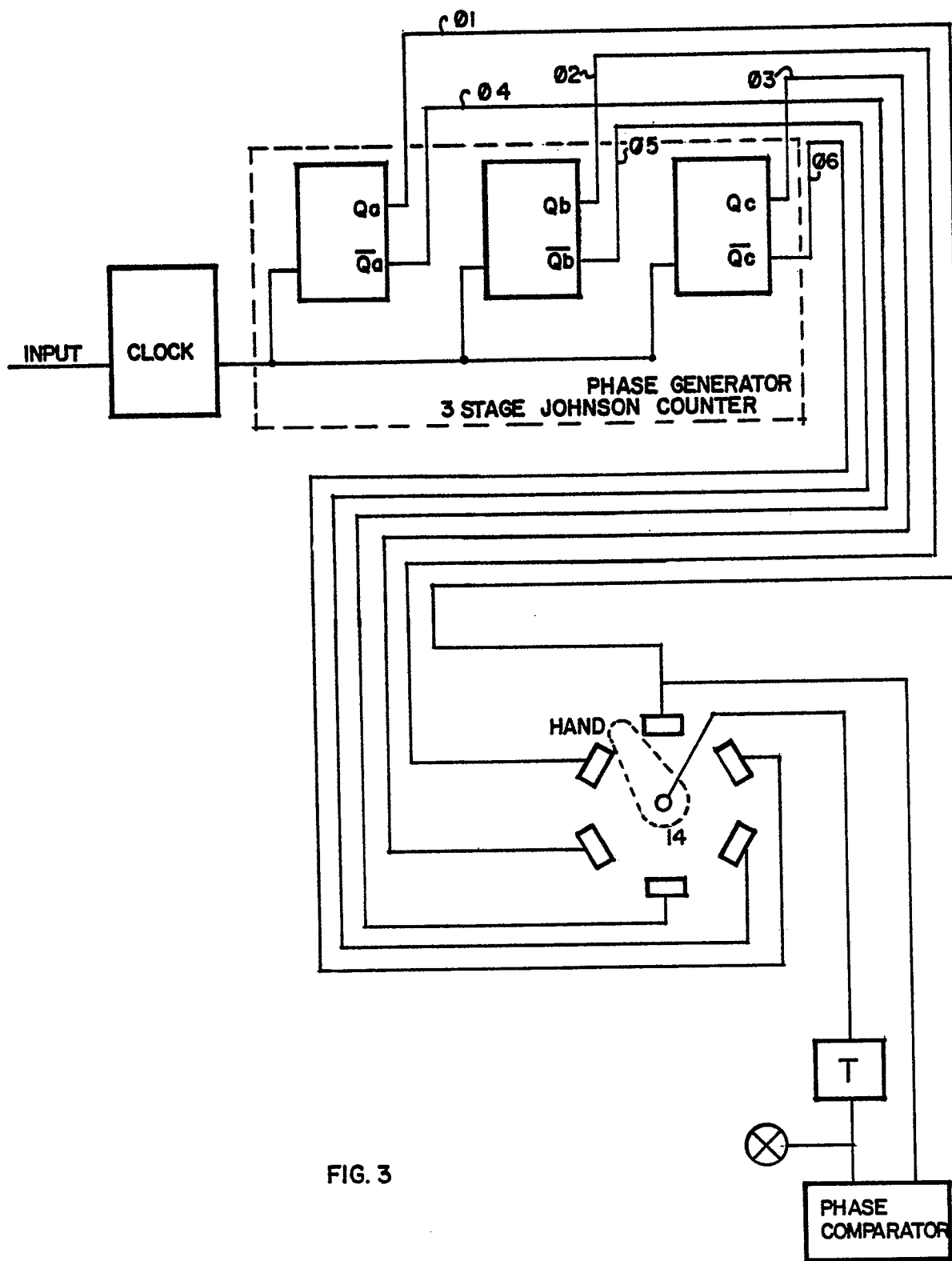


FIG. 3